Italian Society for Climate Sciences
SISC
Venice Mestre - 17-19 October 2018
Sixth Annual Conference
Recent trends in climate sciences, adaptation and mitigation

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The foothill aquifer system of the Piedmont Alpine zone: geology, hydrogeology and groundwater chemistry

Elisa Brussolo(1), Brunella Raco(2), Matia Menichini(2), Marco Doveri(2), Andrea Irace(2), Giulio Masetti(2), Antonello Provenzale(2)

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CENTRO RICERCHE

Globally, groundwater provides (WWDR, 2015; FAO, 2010; WBCSD, 2006)**:**

→ drinking water to more than 50% of the population

→ 43% of the irrigation water

→ 40% of the industrial water

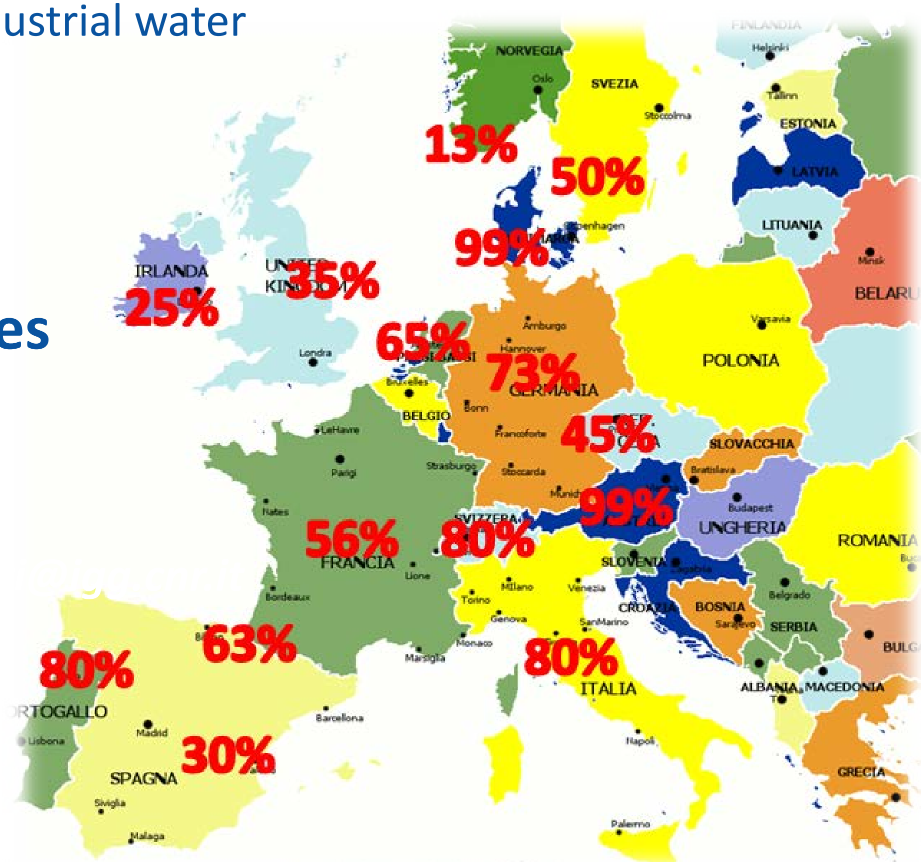
In Europe,

the groundwater exploitation provides

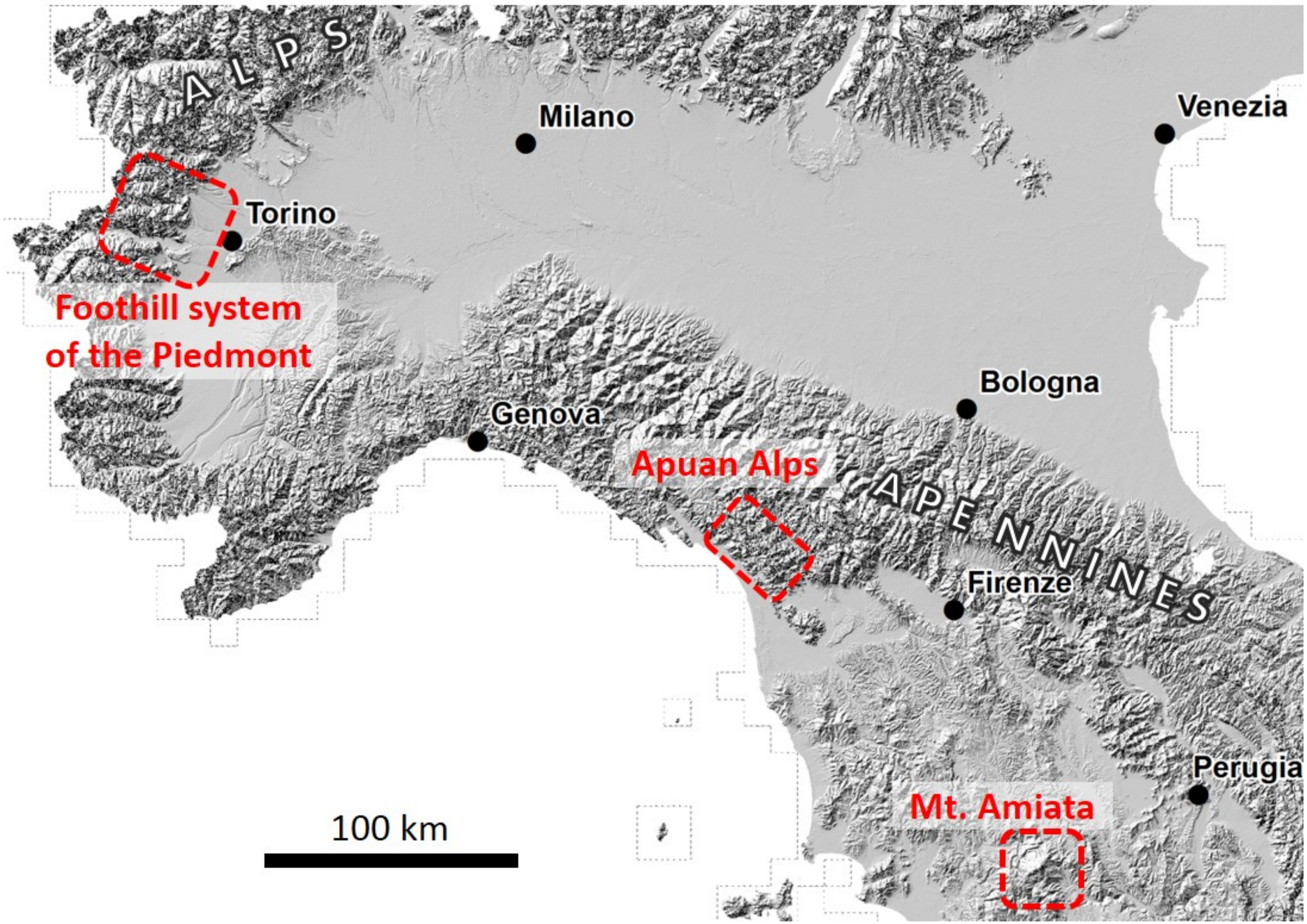
domestic water to the

70% of the population on average

(Martinez et al., 2008)



Aquifer Systems involved in the NEXTDATA project



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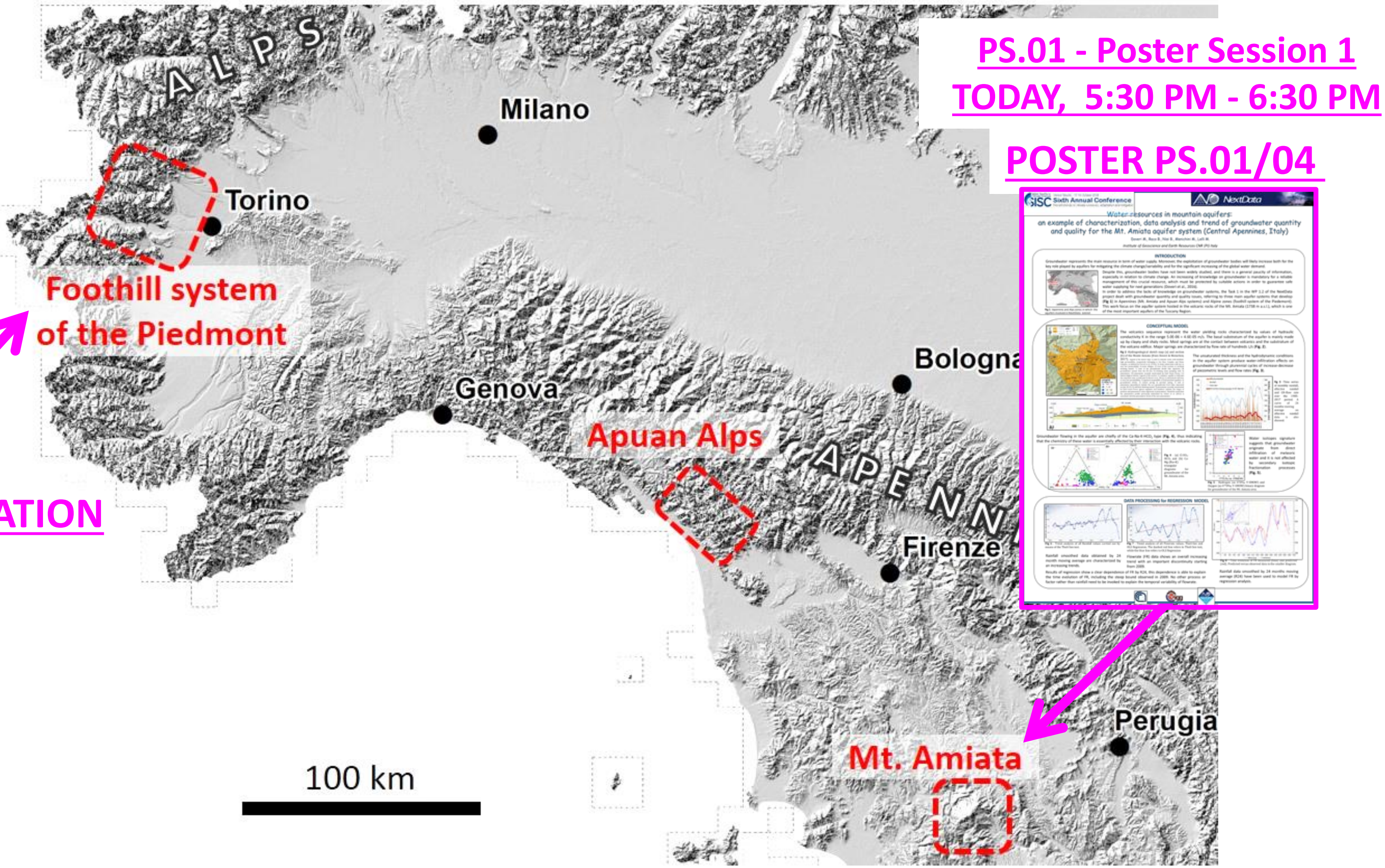

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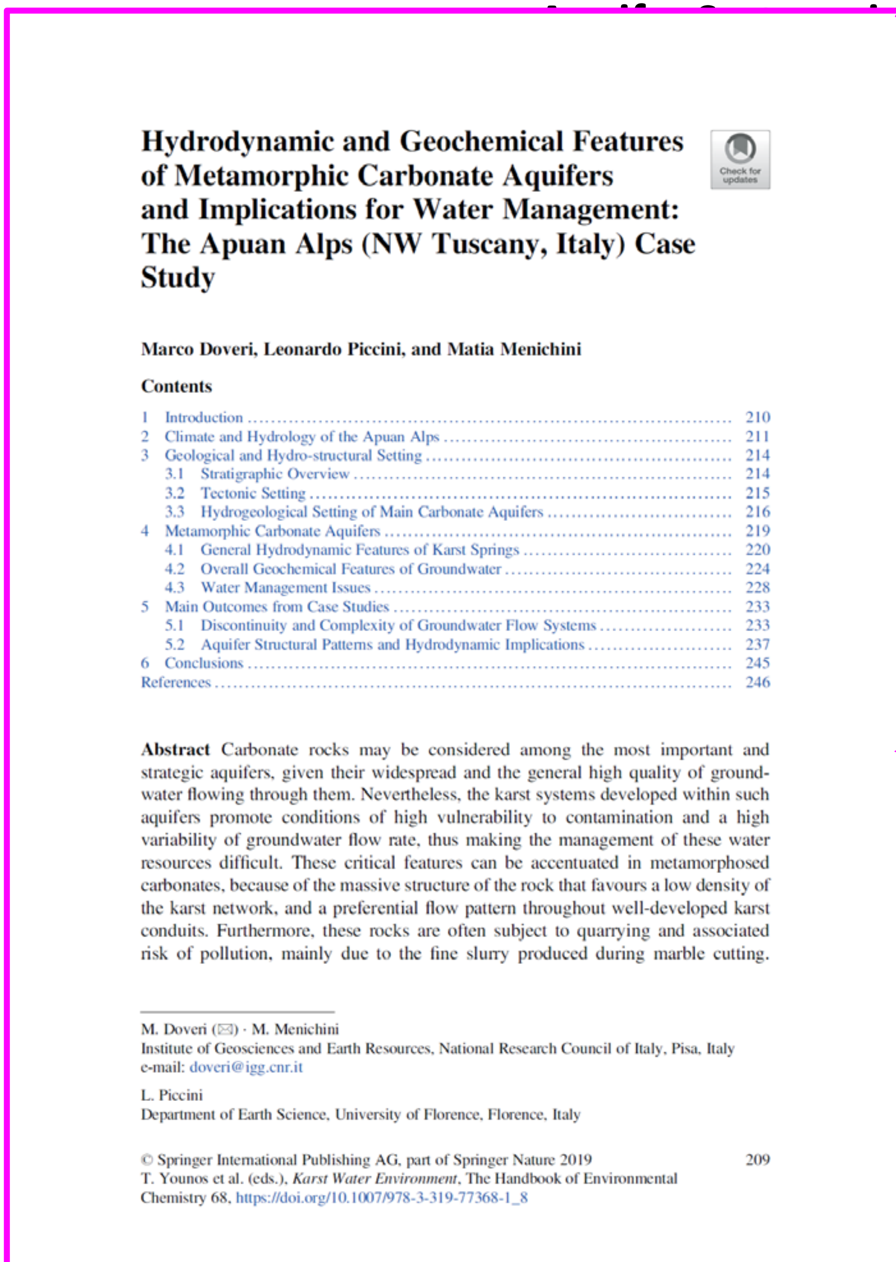

Hydrodynamic and Geochemical Features of Metamorphic Carbonate Aquifers and Implications for Water Management: The Apuan Alps (NW Tuscany, Italy) Case Study

Check for updates

Marco Doveri, Leonardo Piccini, and Matia Menichini

Contents

Abstract Carbonate rocks may be considered among the most important and strategic aquifers, given their widespread and the general high quality of groundwater flowing through them. Nevertheless, the karst systems developed within such aquifers promote conditions of high vulnerability to contamination and a high variability of groundwater flow rate, thus making the management of these water resources difficult. These critical features can be accentuated in metamorphosed carbonates, because of the massive structure of the rock that favours a low density of the karst network, and a preferential flow pattern throughout well-developed karst conduits. Furthermore, these rocks are often subject to quarrying and associated risk of pollution, mainly due to the fine slurry produced during marble cutting.

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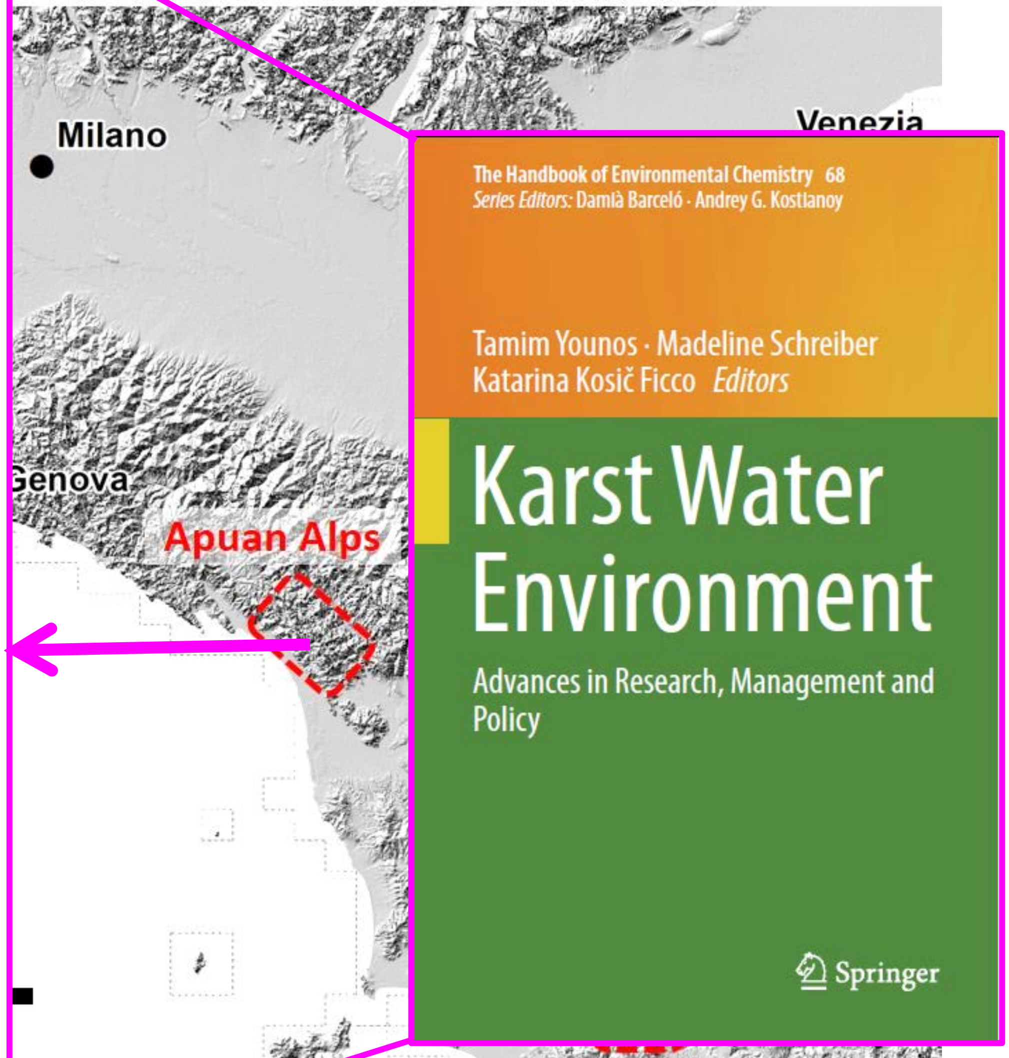
T. Younos et al. (eds.), *Karst Water Environment*, The Handbook of Environmental Chemistry 68, https://doi.org/10.1007/978-3-319-77368-1_8



…of the Piedmont Alpine zone: geology, hydrogeology and groundwater chemistry

GENERAL APPROACH ADOPTED FOR THE STUDIED GROUNDWATER SYSTEMS

- Collection of data and information concerning, geology, hydrology, hydrogeology, water chemistry, water isotopes, etc.. → mainly from publications and available database, plus a few new data;

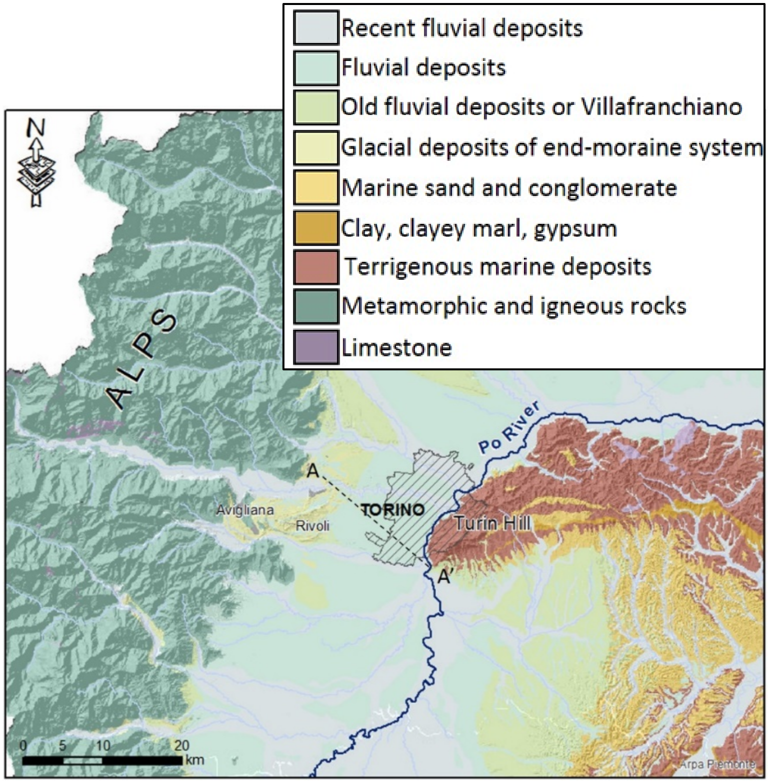
- Elaboration of the aquifers conceptual model by involving and comparing physical and chemical features;

- Trends analysis on the continuous monitoring data, referring to both quantity and quality of groundwater;

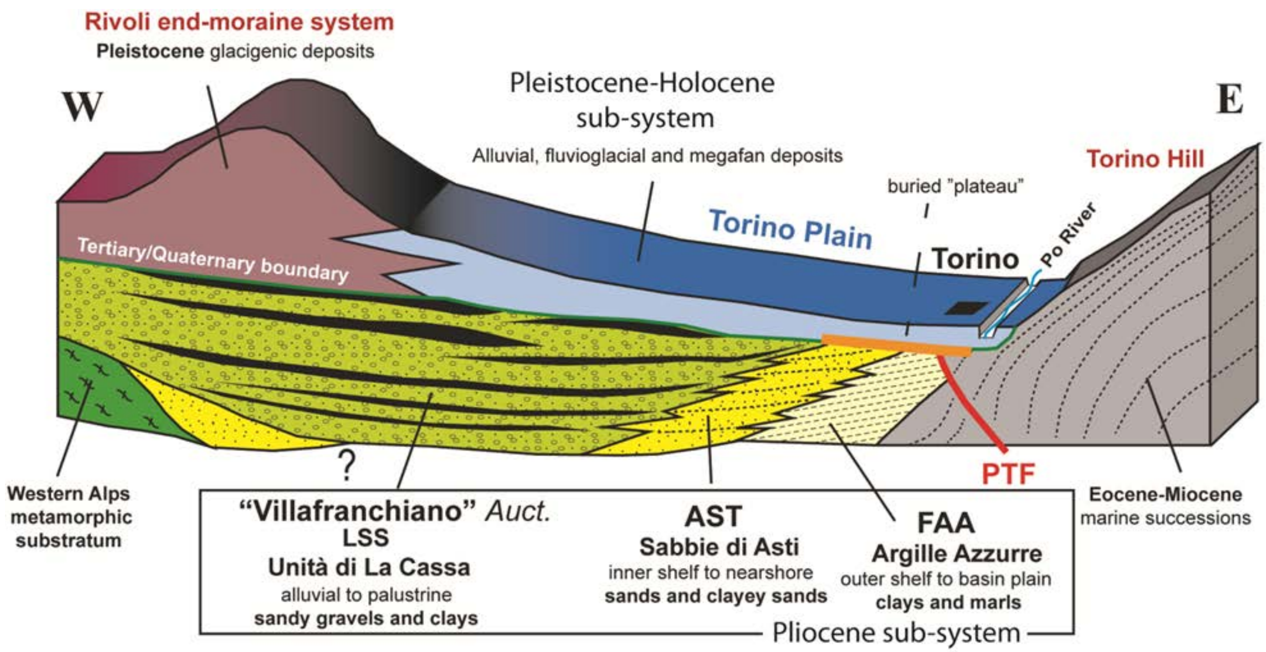
- Development of numerical models throughout either empirical or physically-based approach, accordingly the hydrodynamic conditions of aquifers and the availability of data and information.

The foothill zone of the Piedmont Alps

Simplified geological map
of the western Piedmont



Simplified geological 3D-scheme
(modified from De Luca and Ossella, 2014)



The foothill zone of the Piedmont Alps

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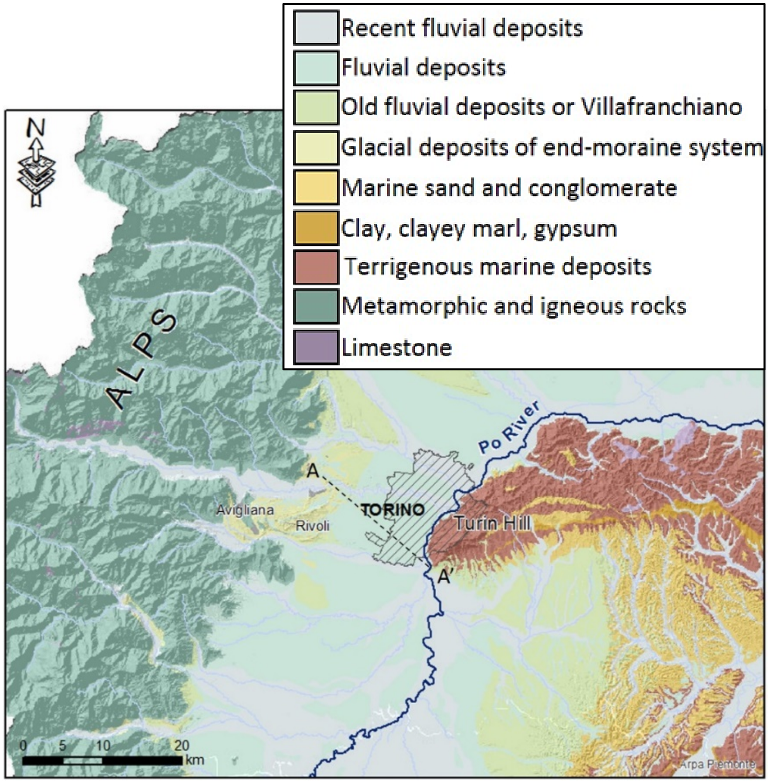

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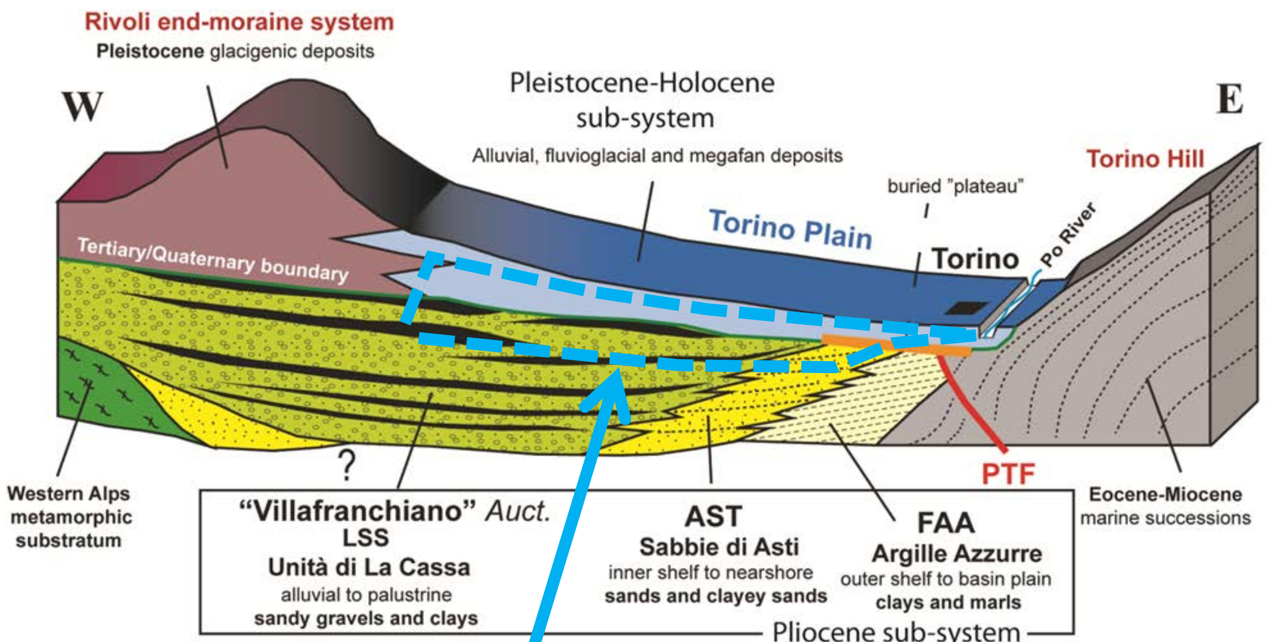
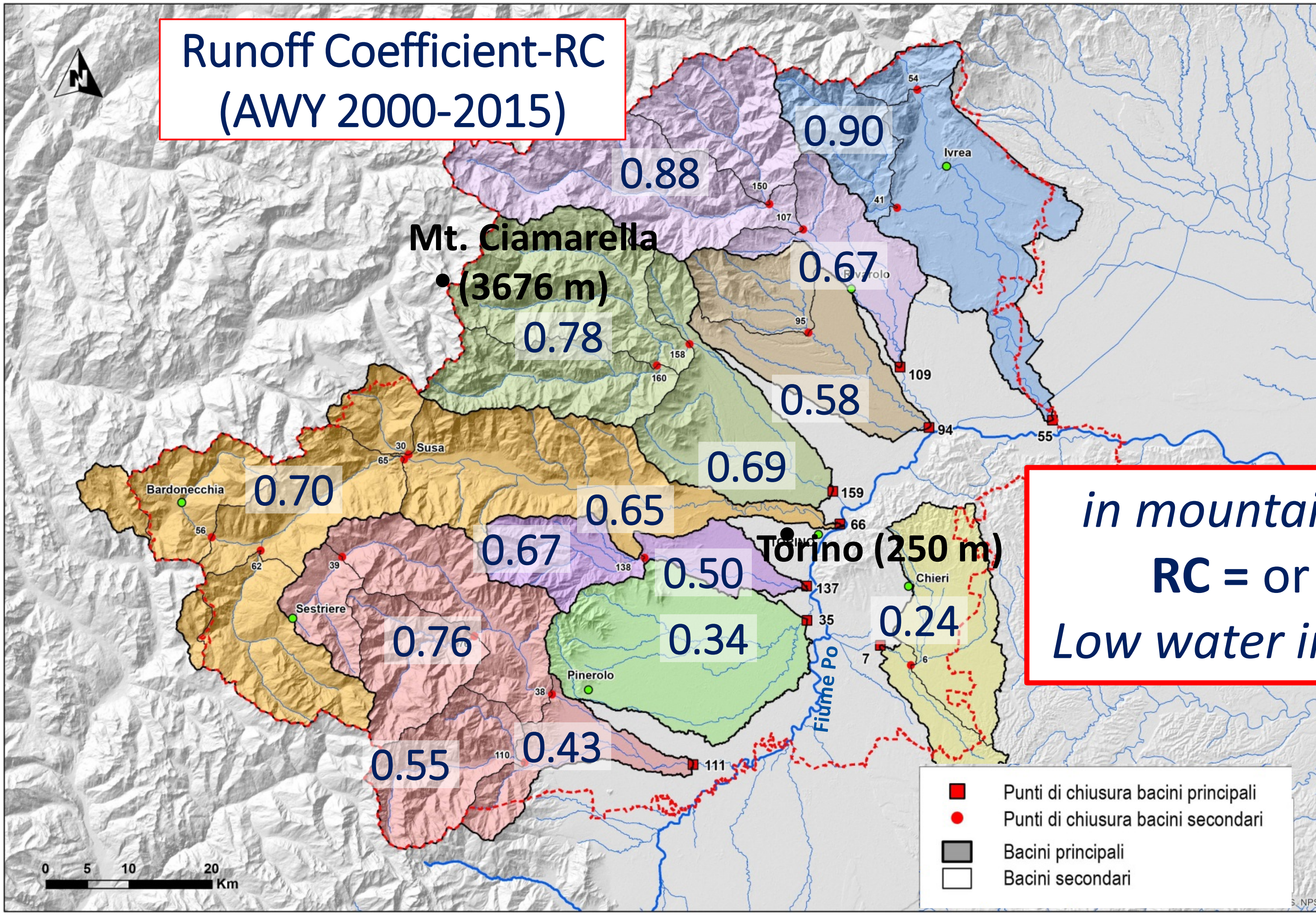


main aquifers exploited for drinking, agricultural, industrial purposes

FROM MONO-LAYER (unconfined or semi-confined), TO MULTI-LAYER

Basin's Rainfall (average water year [AWY] 2000-2015) → 800÷1300 mm



in mountain basins

RC = or > 0.7

Low water infiltration

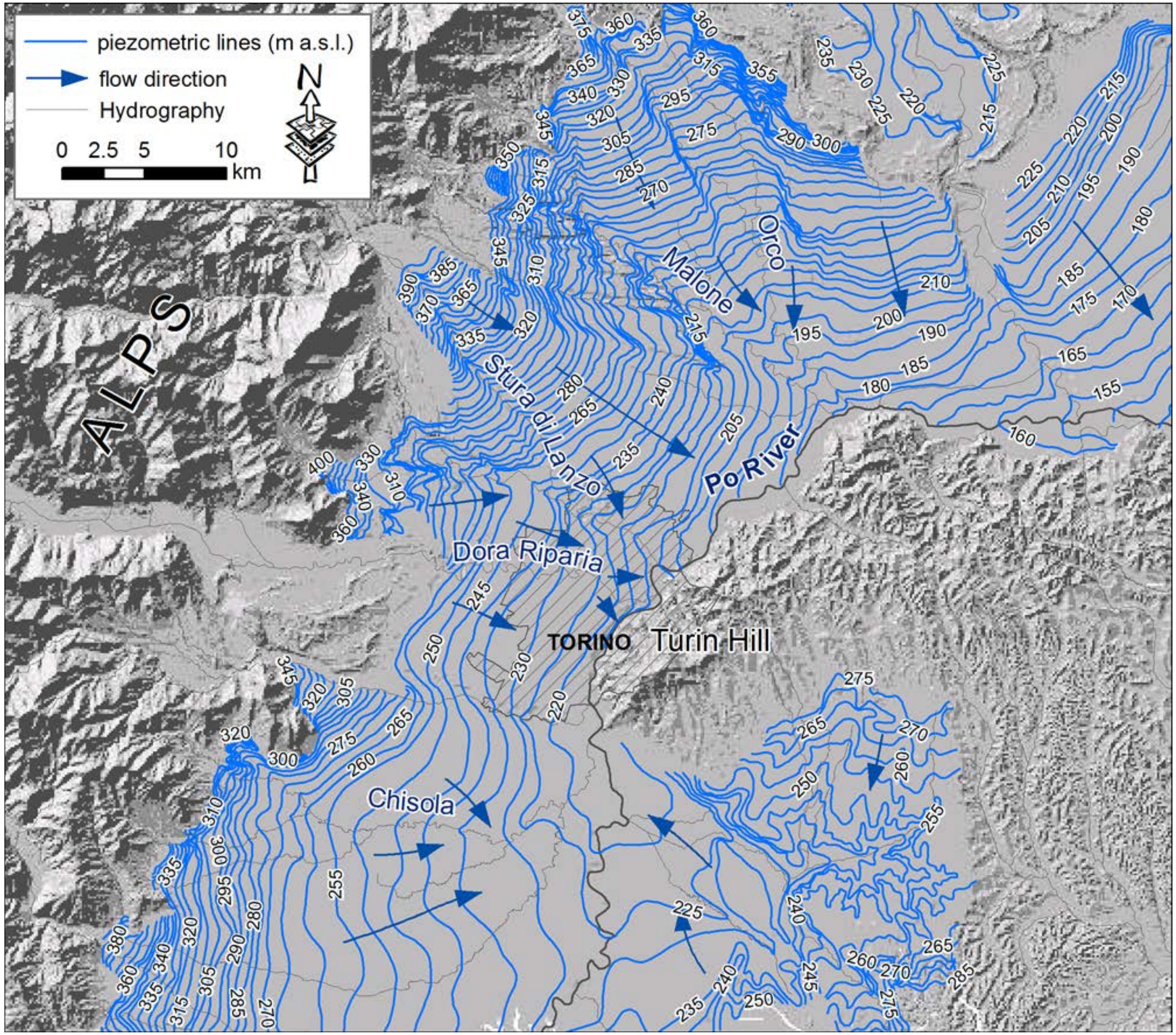
Piezometric map

(data source: www.webgis.arpa.piemonte.it)

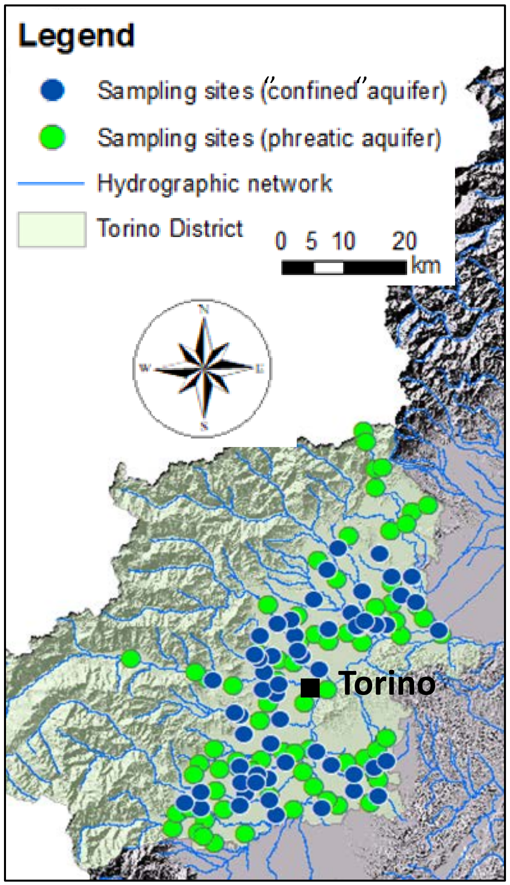
- the Po River acts as the final drainage of the aquifer system

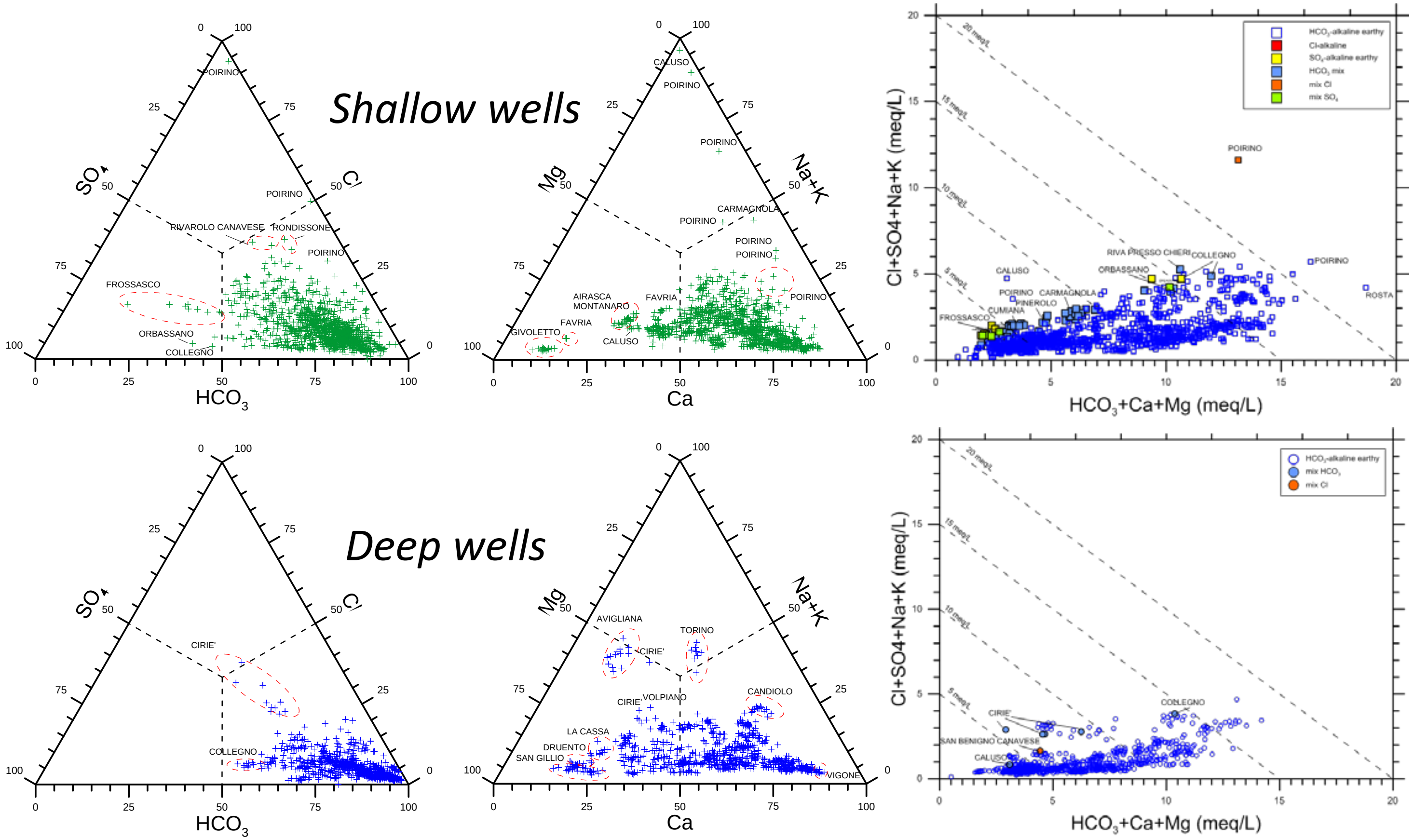
- underground transfers of water from mountain zones, as well as river seepage towards groundwater

- in some sectors, main tributaries act as drainage of the aquifer



Groundwater Chemistry
(raw data from ARPAP database)

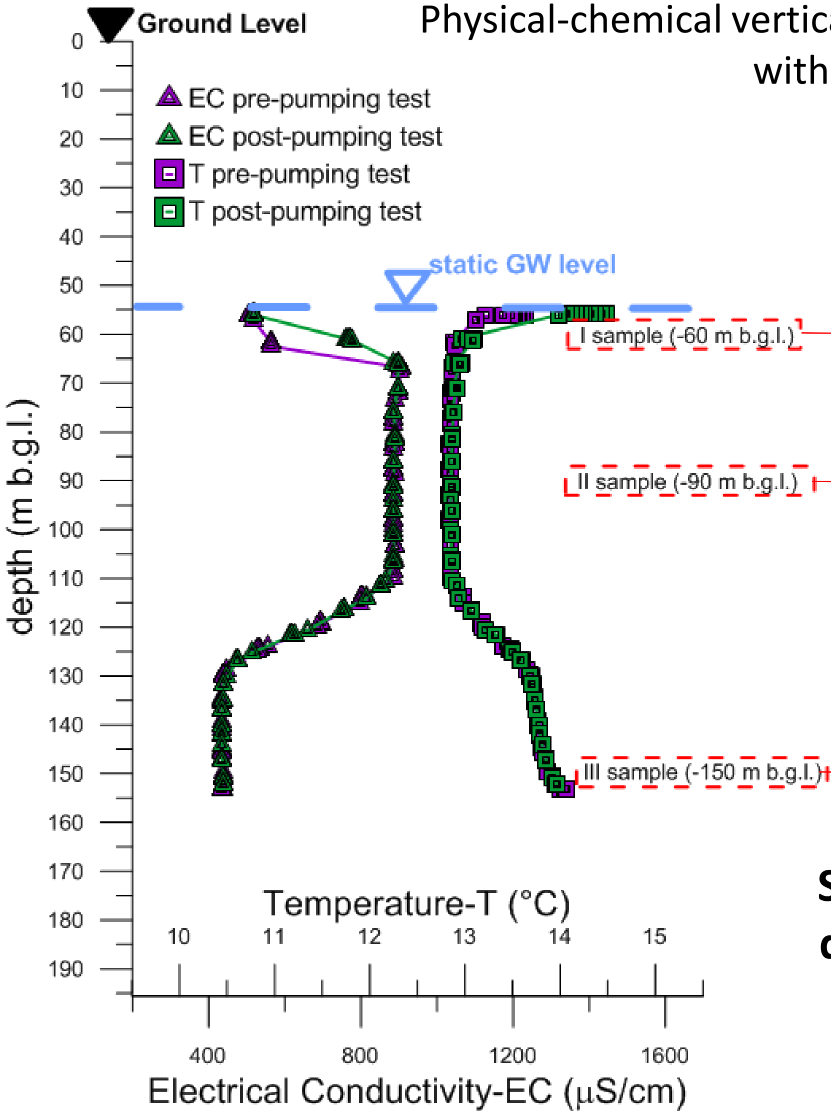




- water are mainly of the Ca(Mg)-HCO_3 type and have a relatively low salinity in both shallow and deep wells →congruence with lithologies;
- shallow wells show slightly wider range and variability over time in terms of concentrations → phreatic flow and its possible connection with rivers;
- major stability and lower salinity in deep wells →"confined" nature of the aquifer system at depth. Nevertheless, local chemical features suggest a possible exchange with the phreatic zone.

Local evidence of the multi-layer character of the system

Physical-chemical vertical log and sampling performed at different depths within multi-screened piezometers



$\delta^{18}O$ (vs. VS-SMOW)

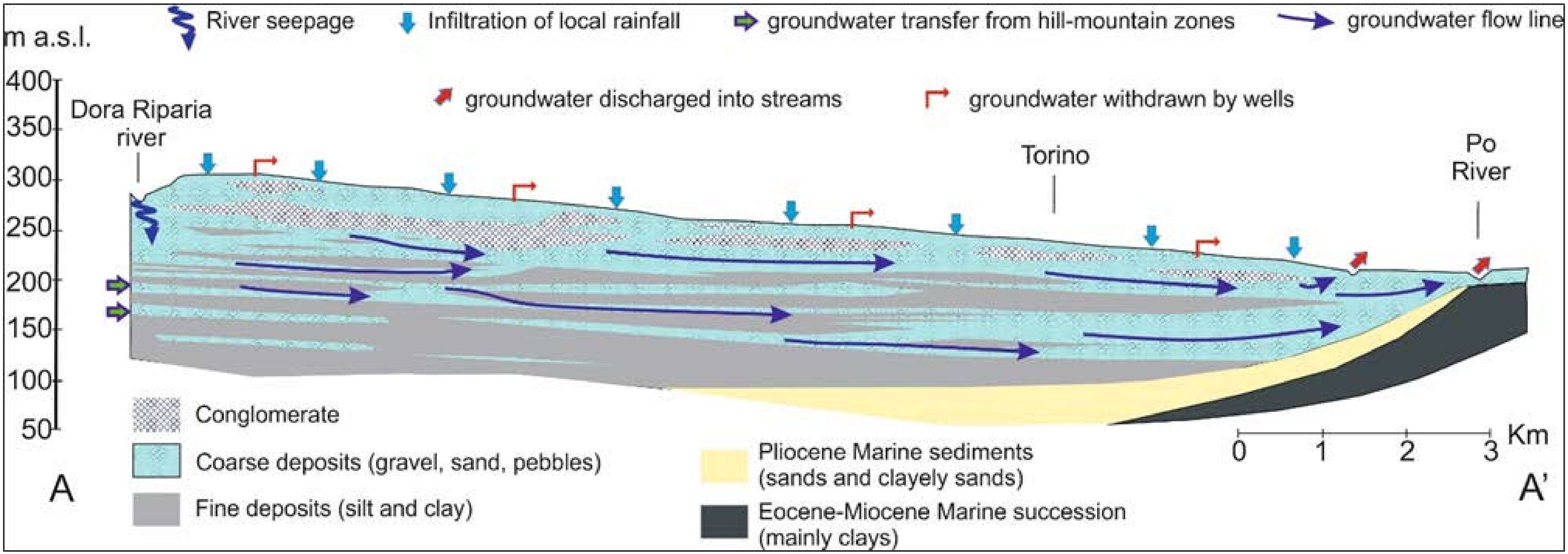
- 9.7‰

- 9.5‰

- 10.0‰

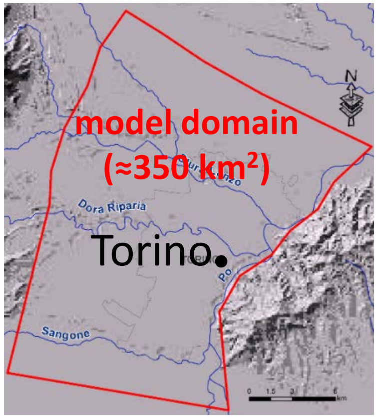
Significant differences with depth in terms of EC, T and water isotope signature (3 groundwater inputs)

Schematic model of groundwater flow-paths, inputs and outputs



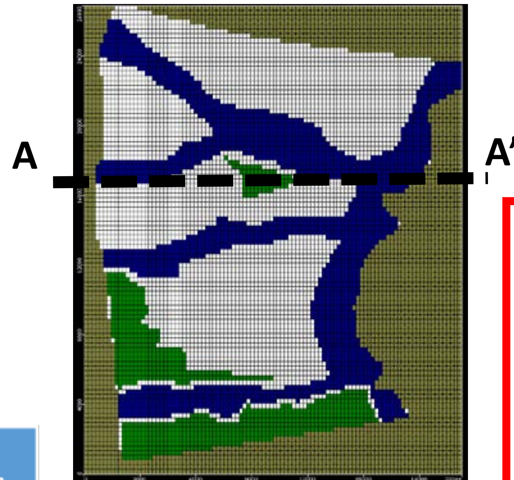
3D numerical model of groundwater flow (steady-state → transient)

Implementation of the model



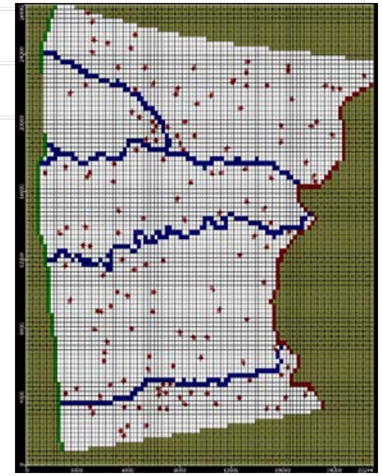
	Kx=Ky (m/s)	Kz (m/s)	Sy	Ss (1/m)
	2.5E-03	2.5E-04	0.25	
	1.5E-03	1.5E-04	0.1	
	1E-04	1E-05	0.05	
	1E-06	1E-07		0.001
	4E-04	4E-05		0.0001

Active domain and spatial discretization



Hydrologic boundary conditions

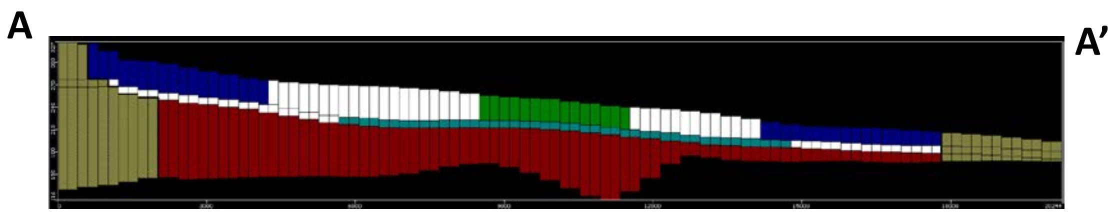
	General Head Boundary (GHB)
	Constant Head
	River
	No flow



Modflow FD code (USGS)

GUI: Visual Modflow

Hydrodynamic parameters



Hydrologic sink and source terms

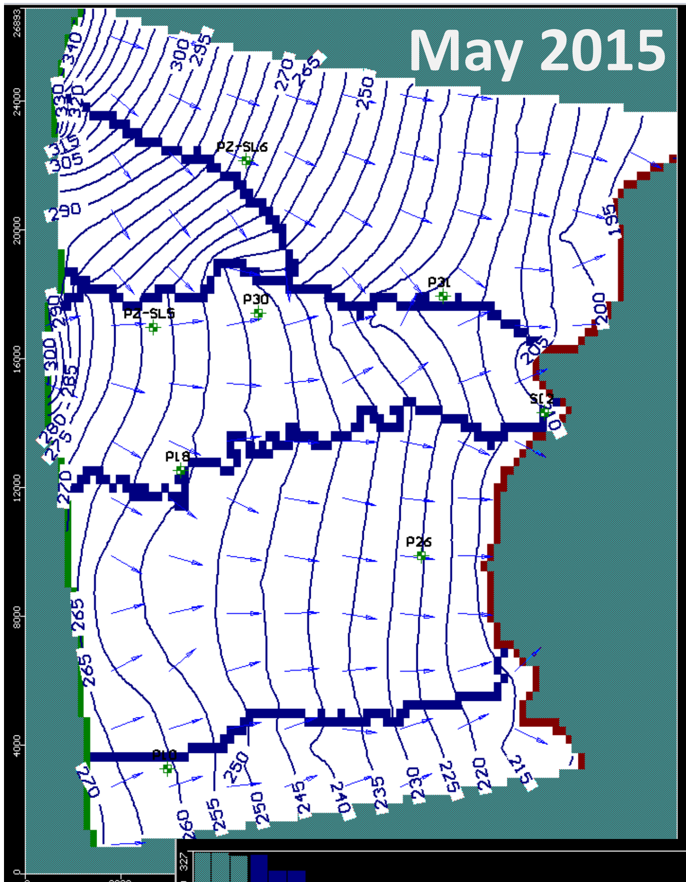
Recharge

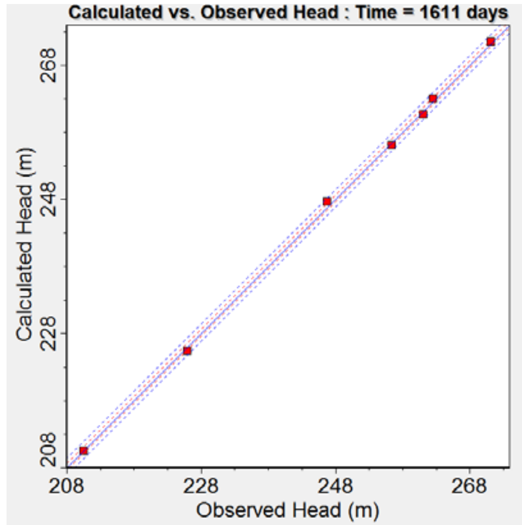
Starting from the ***Yearly Water Balance of the Piedmont Alpine Zone*** (***Brussolo et al., 2018 – in the poster session of this conference***): ***For the Steady State model***, 600 mm as mean value of "yearly actual renewable water resource" (GW+SW) was translated in recharge by using infiltration coefficient (IC) - Urban area → 150 mm (I.C. 25%); Rural area → 350 mm (I.C. 60%); ***For the Transient model,*** monthly values from Jan. 2011 to Dec. 2015 were implemented.

Well pumping rate

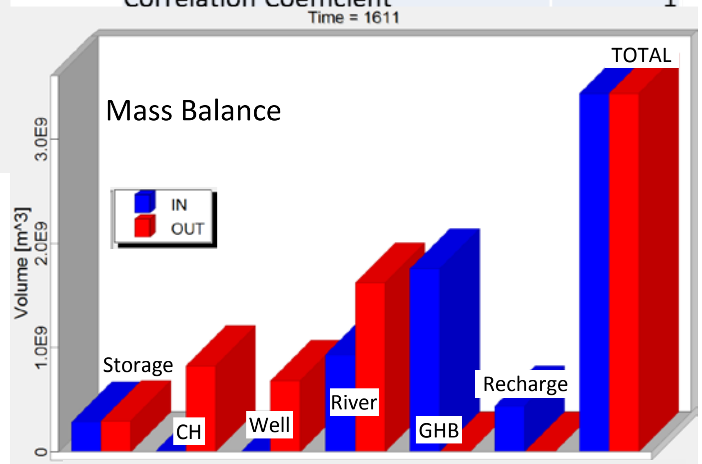
Drinking water → about 77 Mm^3/yr
Industrial well → about 66 Mm^3/yr
Agricultural purpose → about 11.5 Mm^3/yr
Domestic wells → about 0.05 Mm^3/yr

3D numerical model of groundwater flow

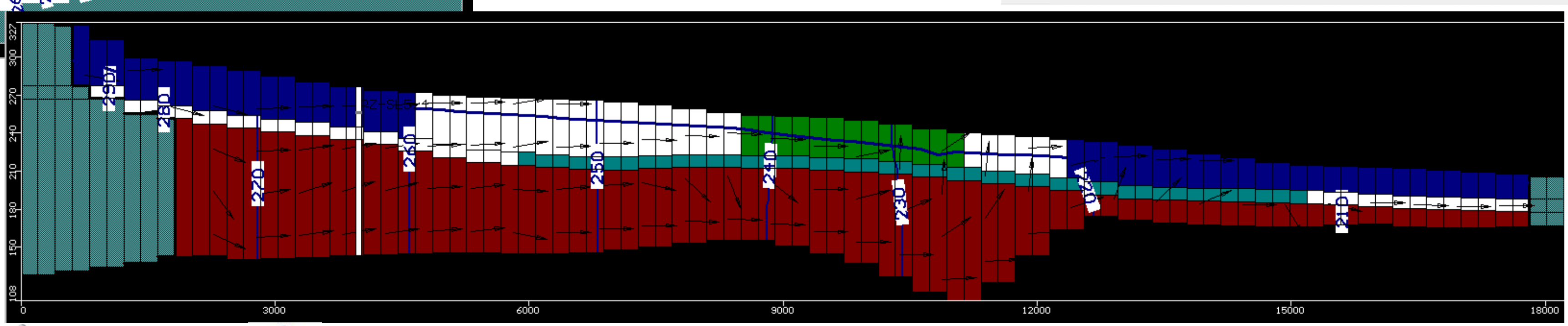




Statistics	May 2015
Max Residual (m)	1.012
Min Residual (m)	0.114
Reasidual Mean (m)	0.175
Abs Residual Mean (m)	0.455
Standard Error of the estimate (m)	0.205
Root Mean Squared (m)	0.532
Normalized RMS (%)	0.877
Correlation Coefficient	1

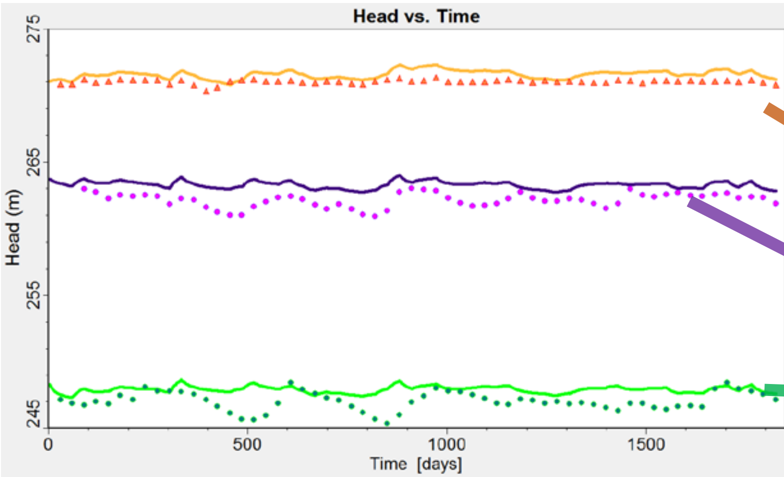


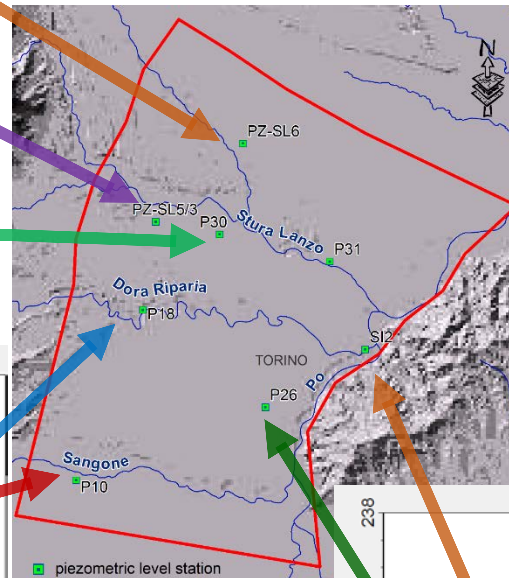
Model Calibration and Result (transient model)



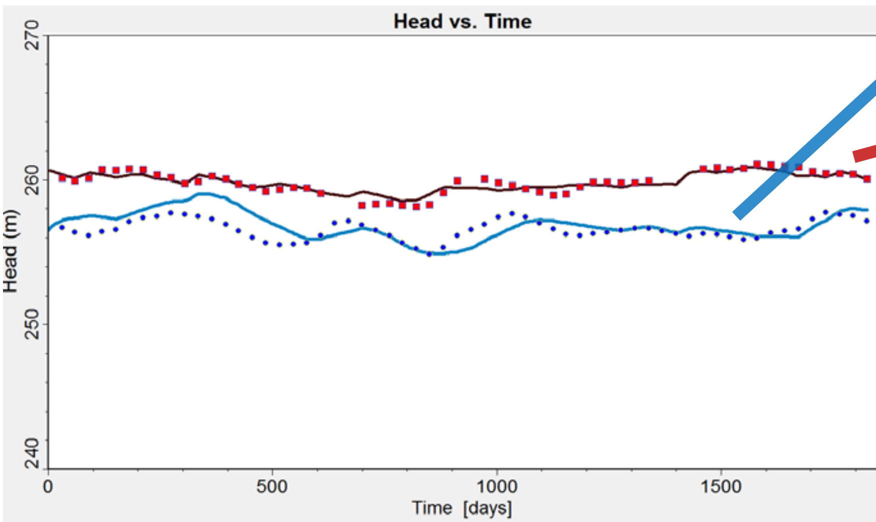
3D numerical model of groundwater flow

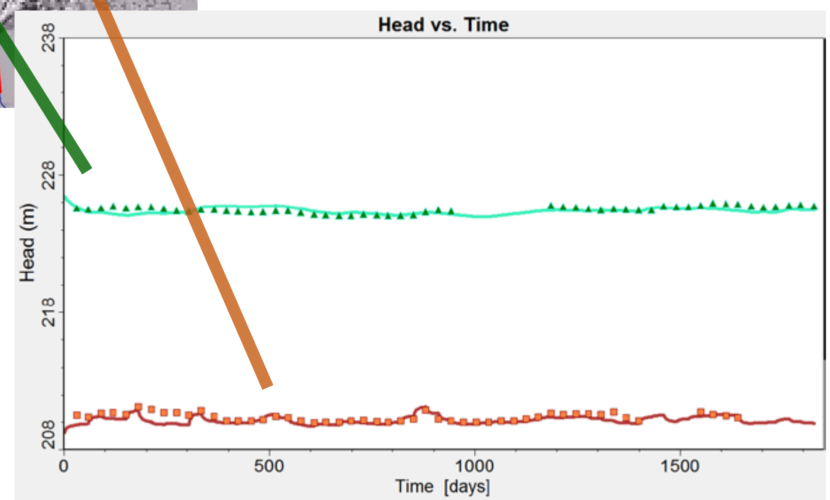
Model Calibration and Result





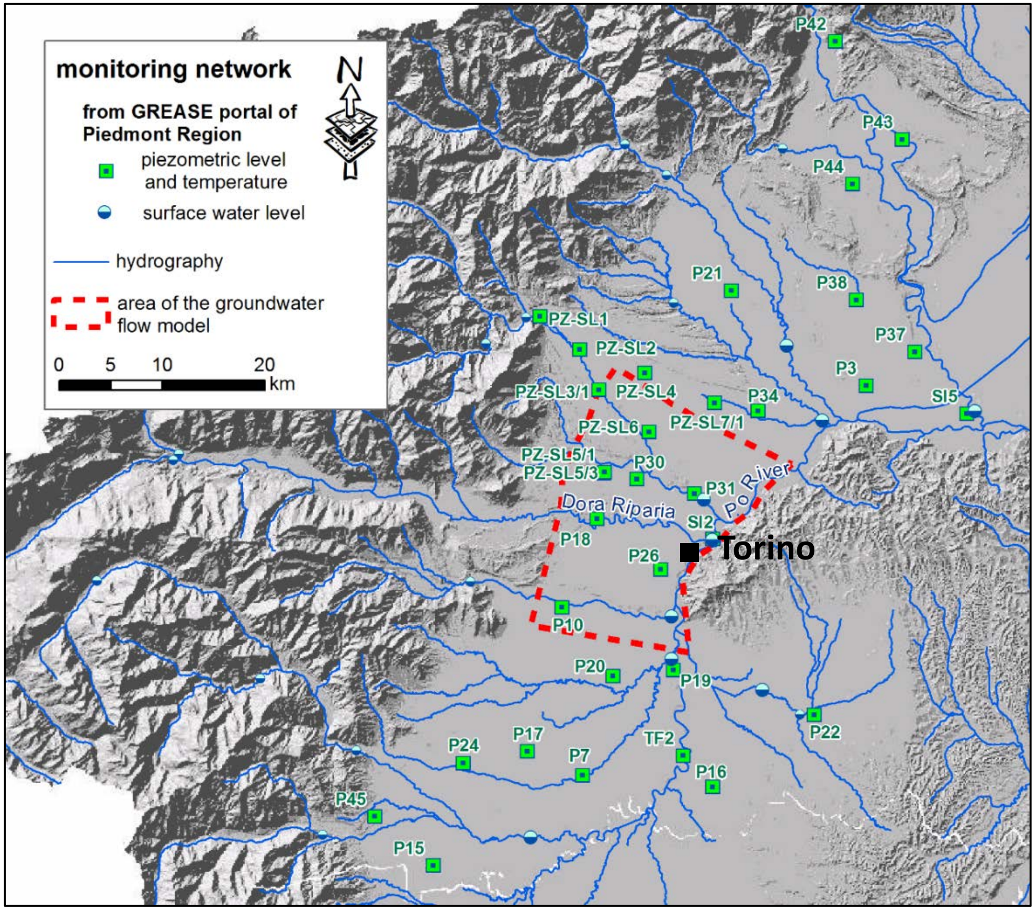
P10/4(Observed)
P10/4Interpolated
P18/4(Observed)
P18/4Interpolated
P26/4(Observed)
P26/4Interpolated
P30/4(Observed)
P30/4Interpolated
PZ-SL5/4(Observed)
PZ-SL5/4Interpolated
PZ-SL6/4(Observed)
PZ-SL6/4Interpolated
SI2/4(Observed)
SI2/4Interpolated



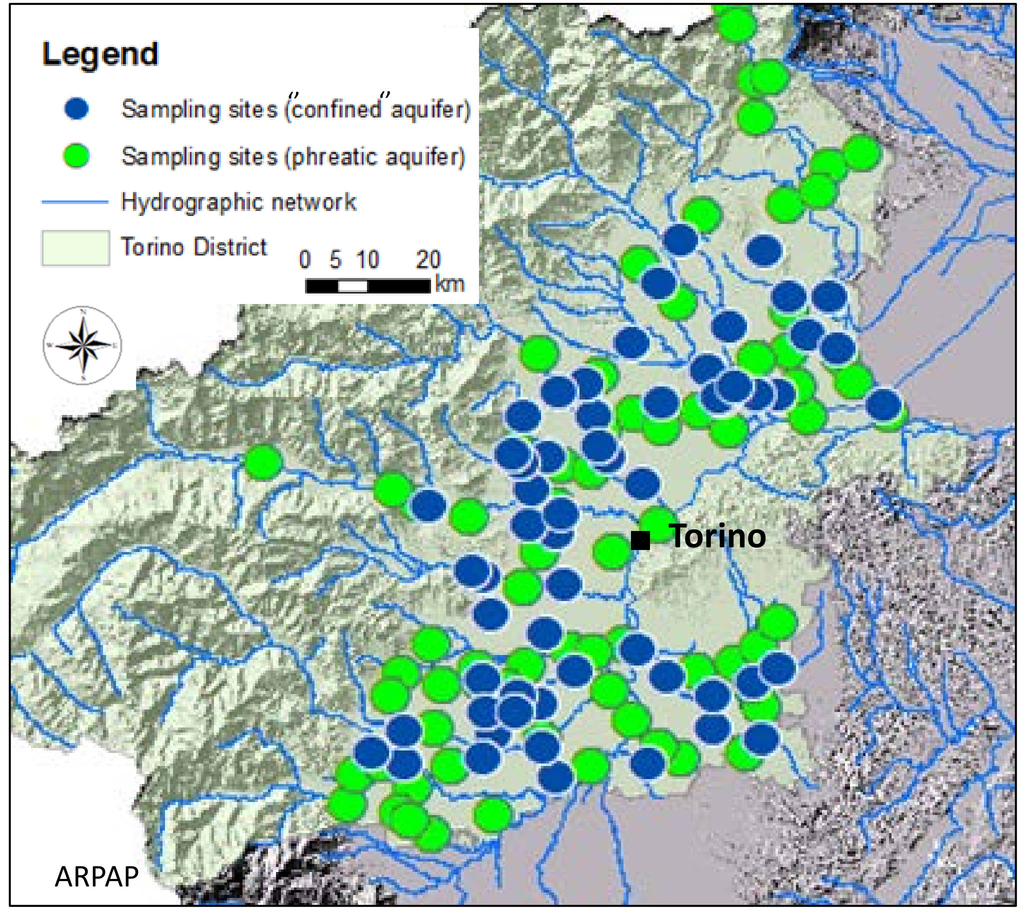


Trend analysis of time series of piezometric level and chemical concentration

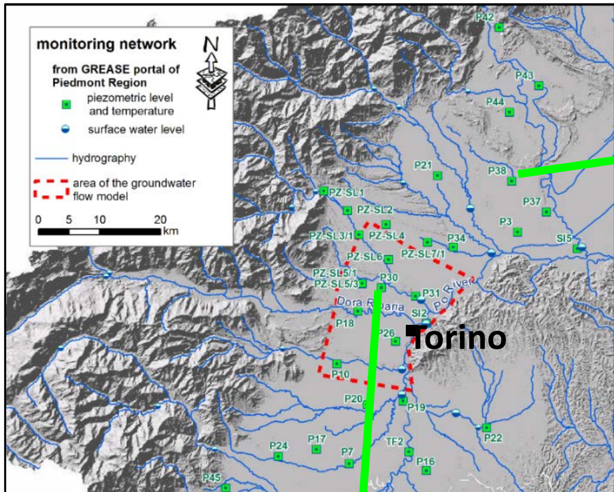
Network of piezometers

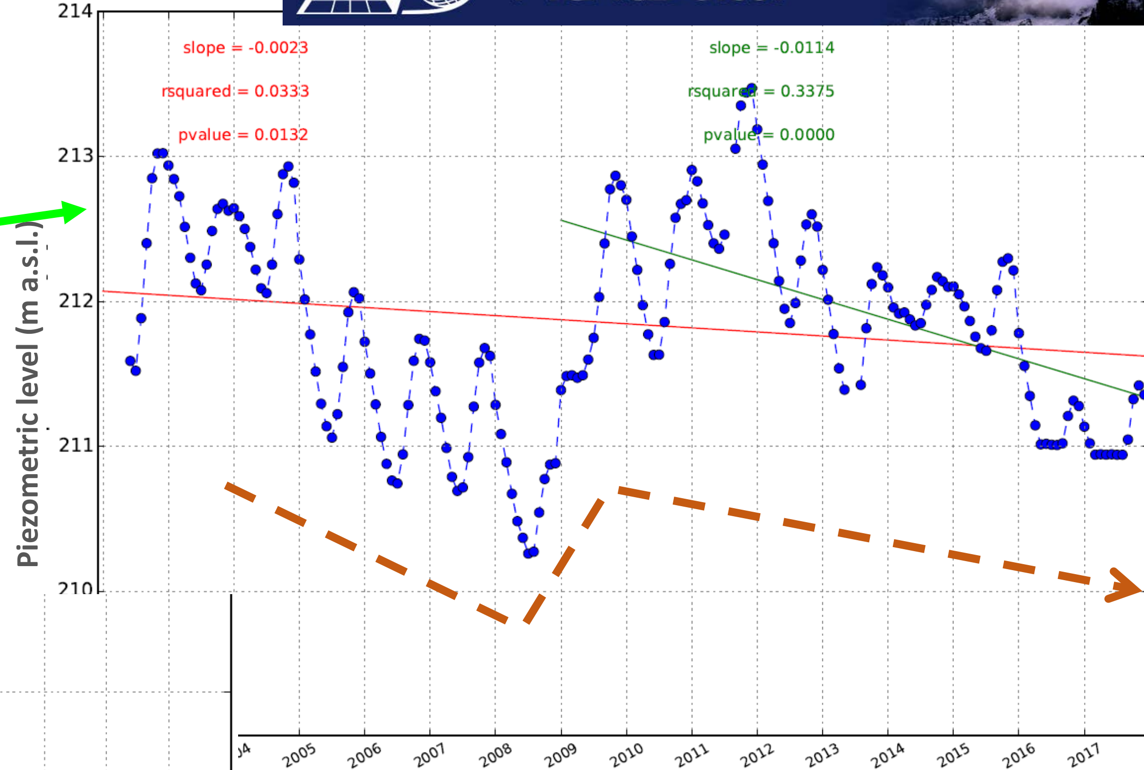


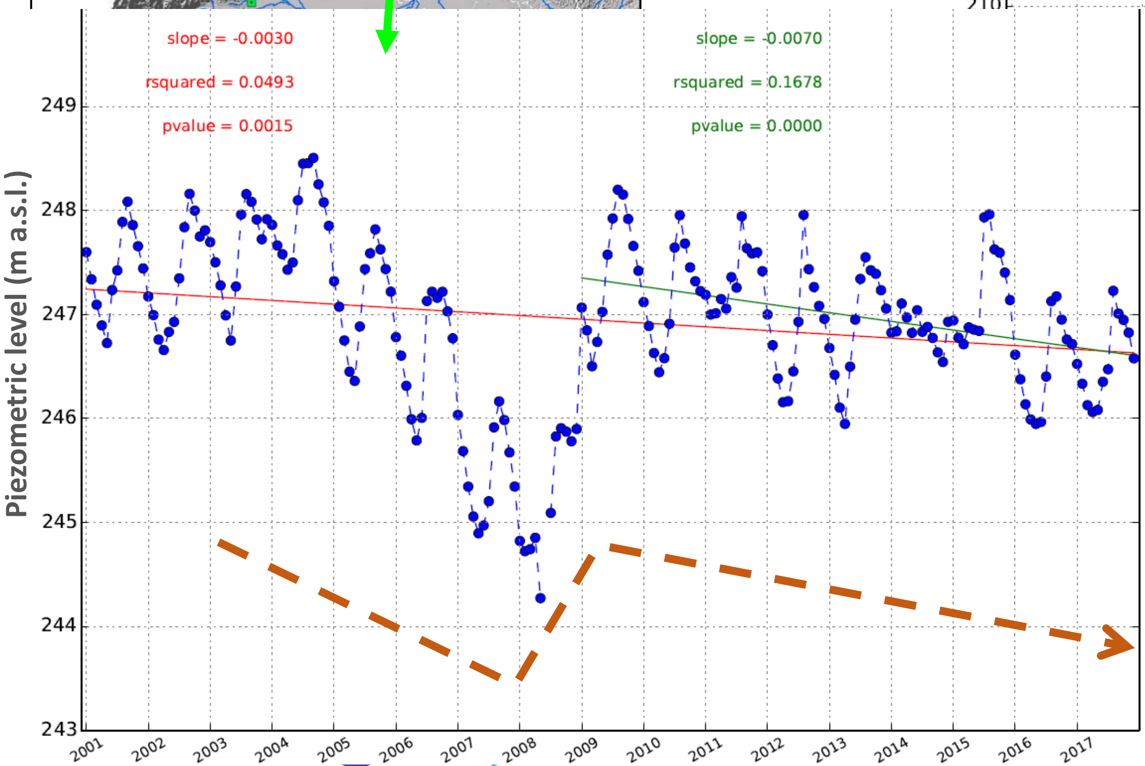
Network of wells for chemical monitoring



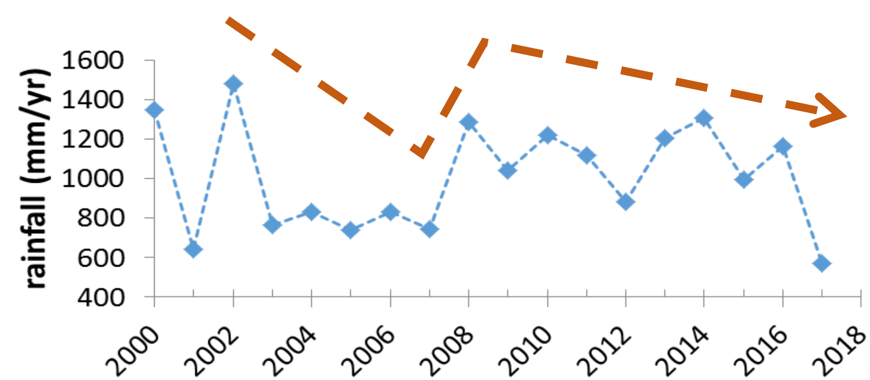
Trend analysis of monthly piezometric levels





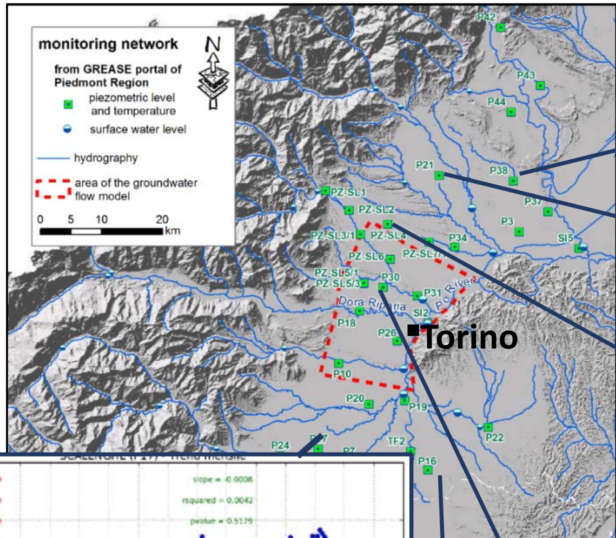


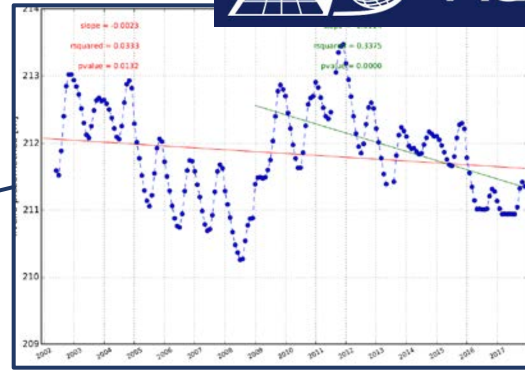
Yearly rainfall (average among some basins)

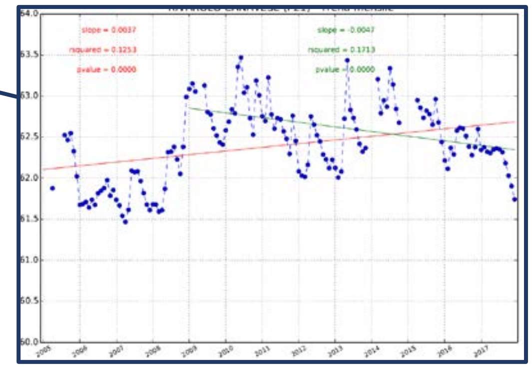


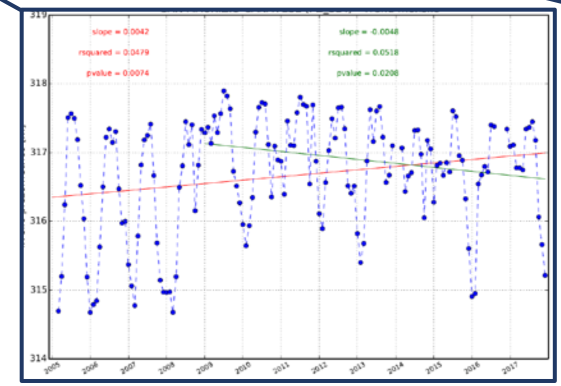
…pine zone: geology, hydrogeology and groundwater chemistry

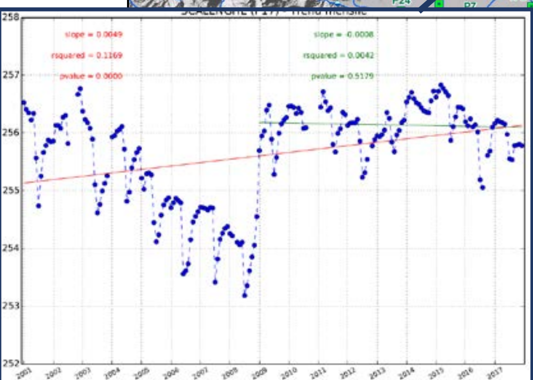
Trend analysis of monthly piezometric levels

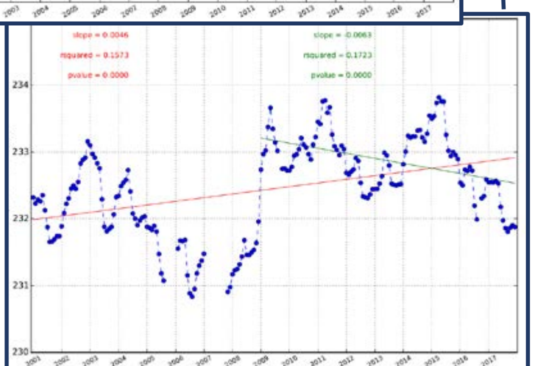


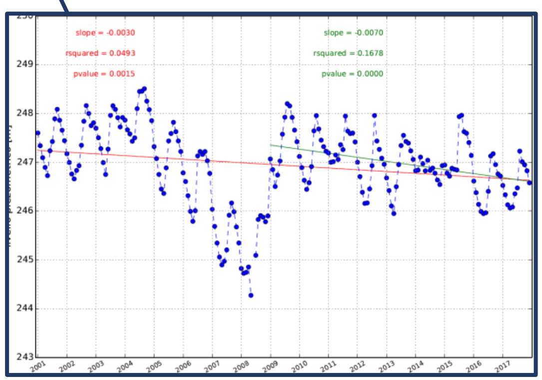












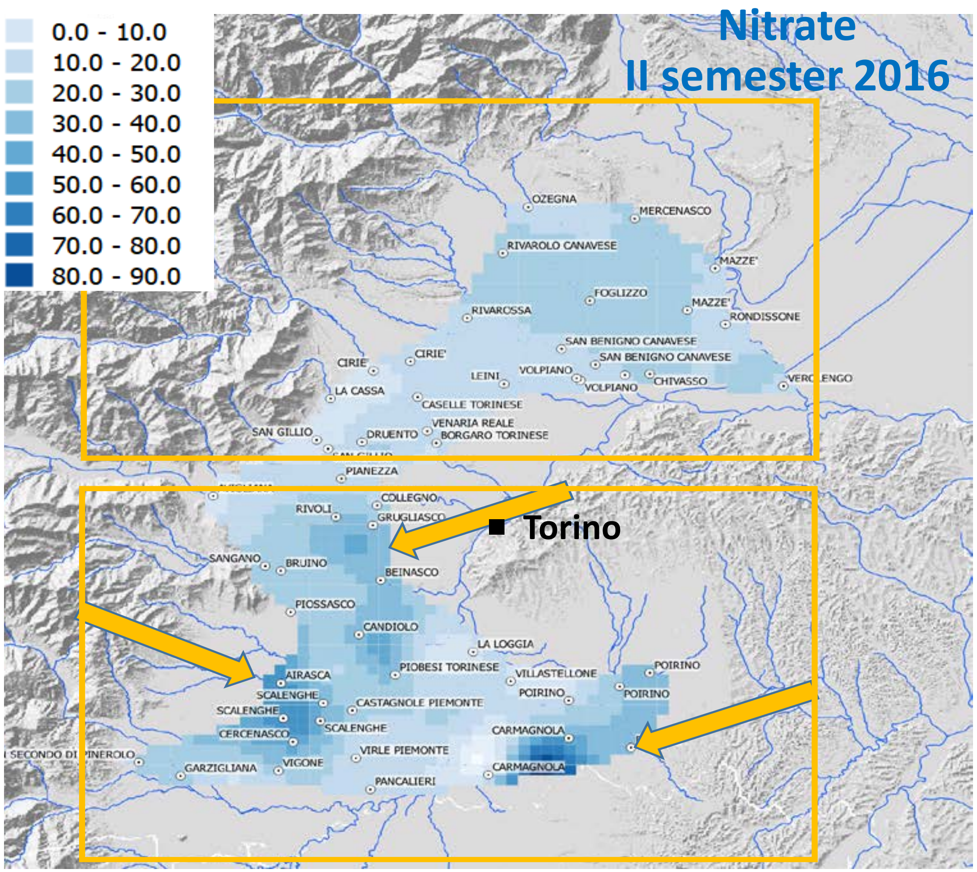
Similar behavior of piezometric levels across the area

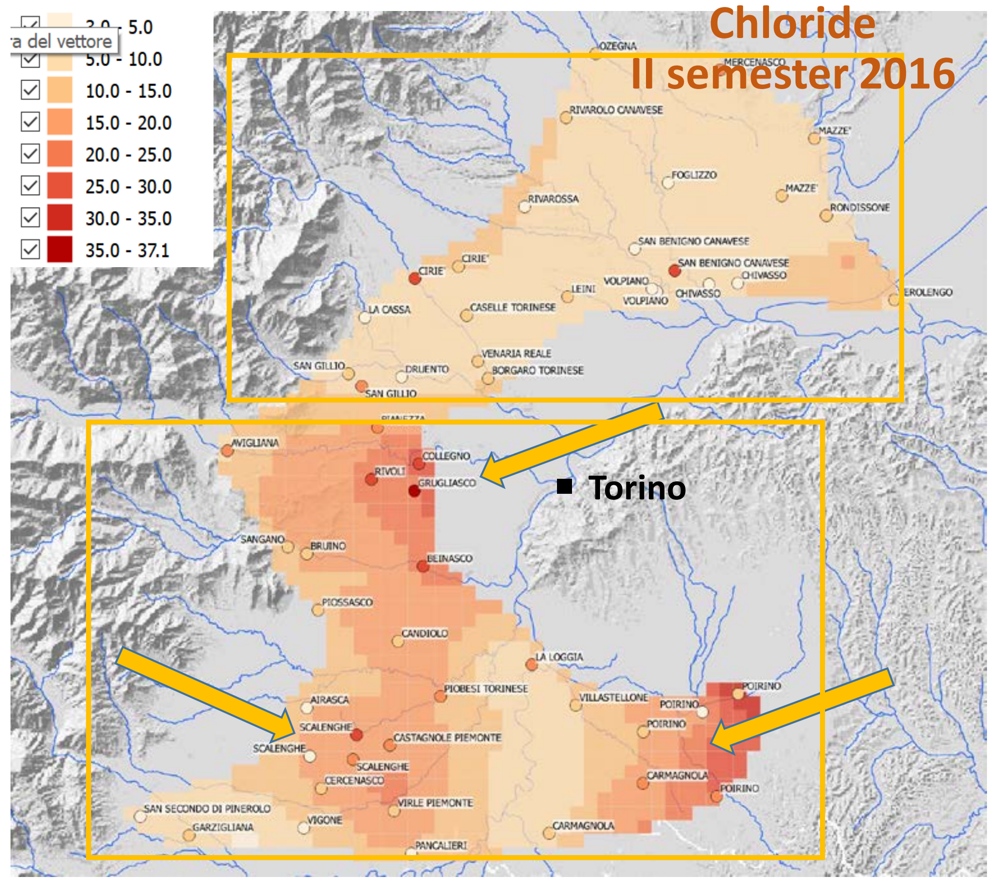
Sharp increase in 2008/2009 (of the order of 3m) as response to a rainier period.

Over the 2009-2017 period, most piezometers shows a significant trend of GW decreasing

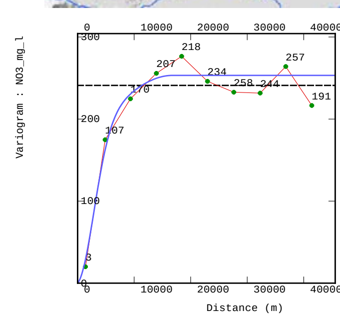
Confidence level of the trend 95% to 99%

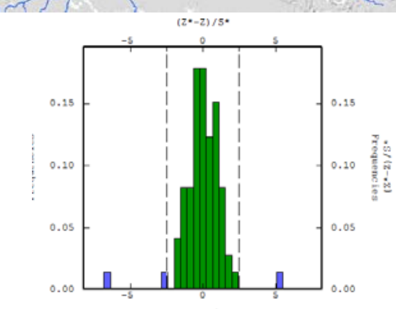
Trend analysis of chemical data (zones with higher concentrations)



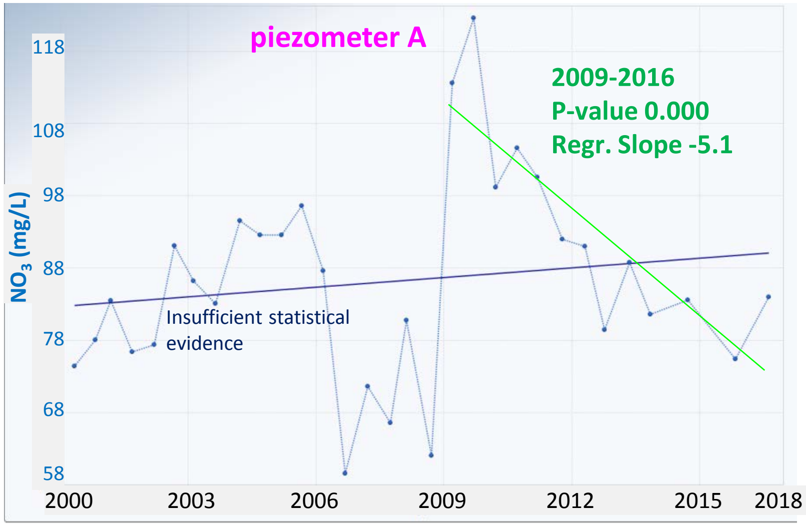


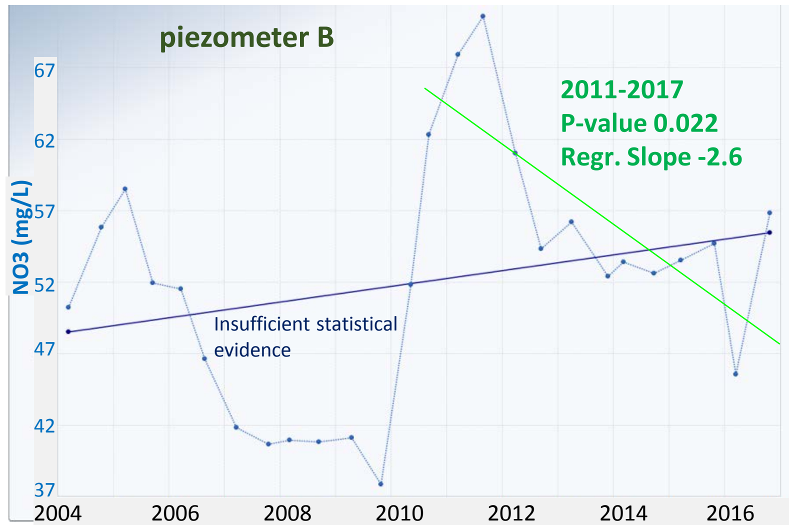
Maps elaborated by means of Lognormal Kriging estimator, after the study of the experimental variogram and the cross-validation

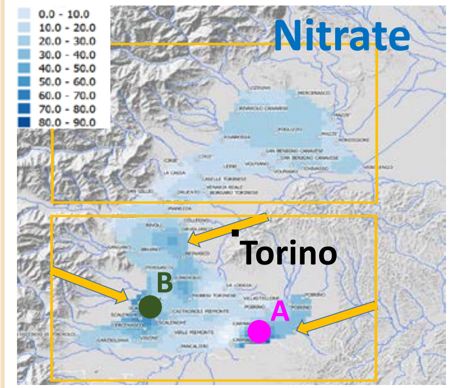


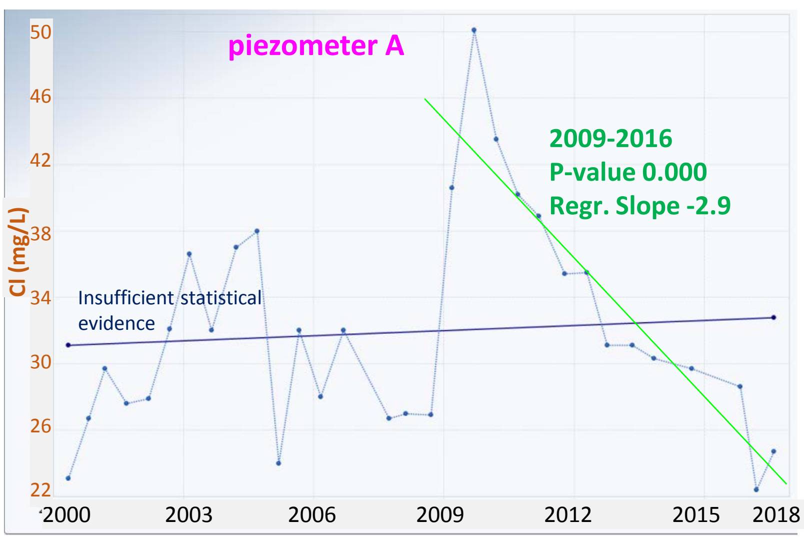


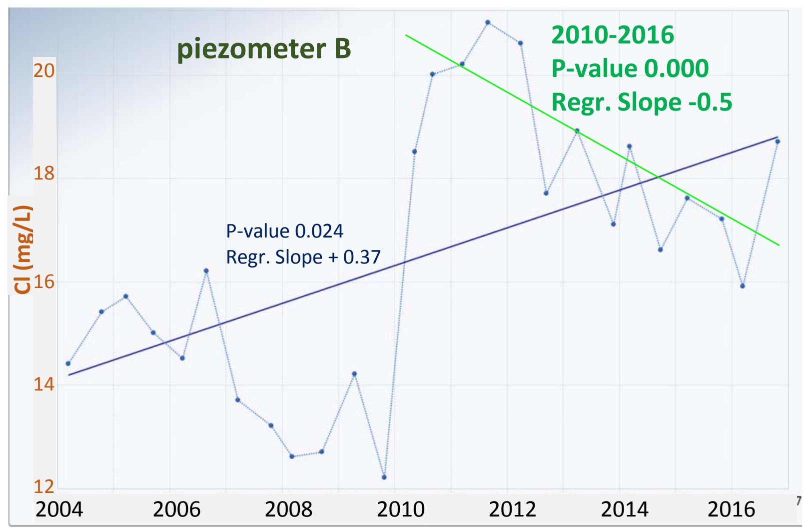
Trend analysis (Mann-Kandall) of chemical data (zones with higher concentrations)

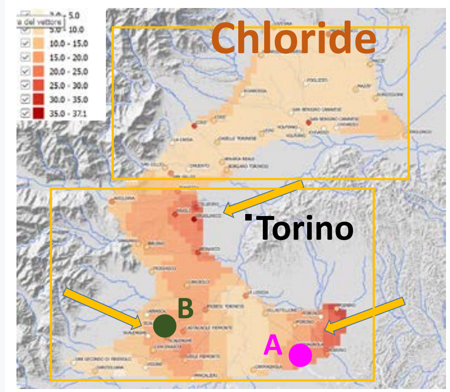






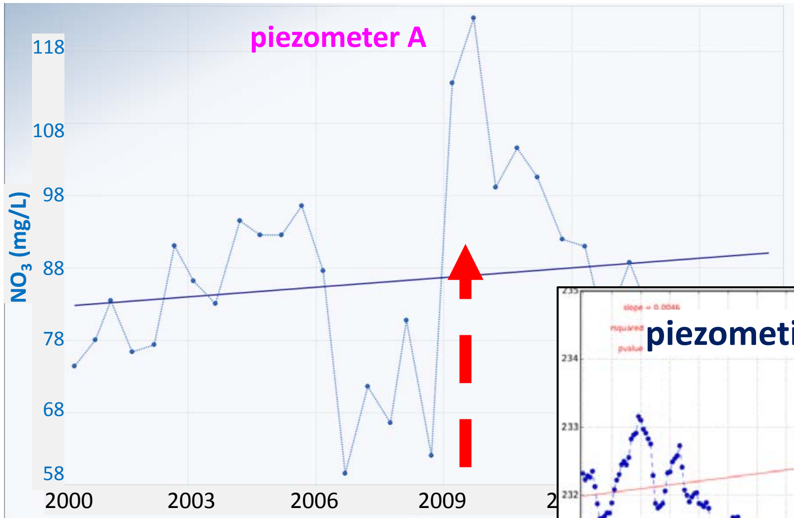


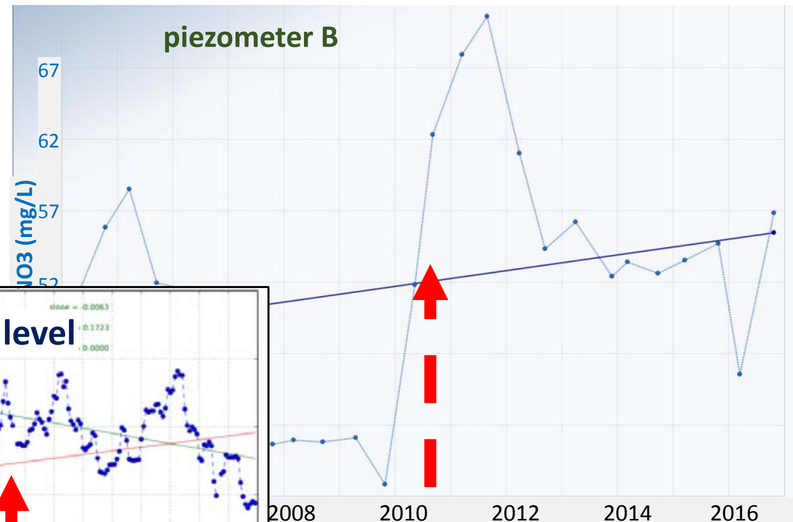


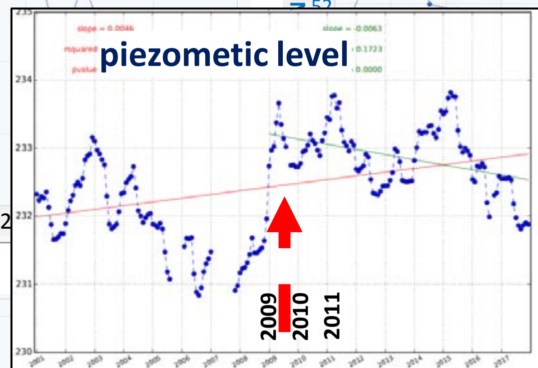


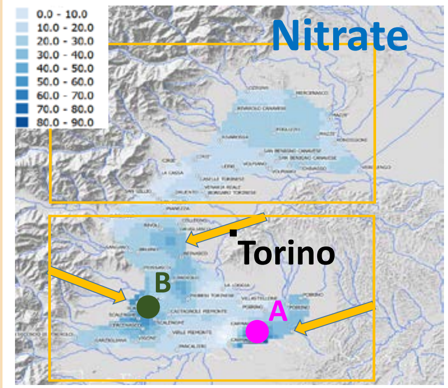
The foothill aquifer system of the Piedmont Alpine zone: geology, hydrogeology and groundwater chemistry

Trend analysis of chemical data (zones with higher concentrations)

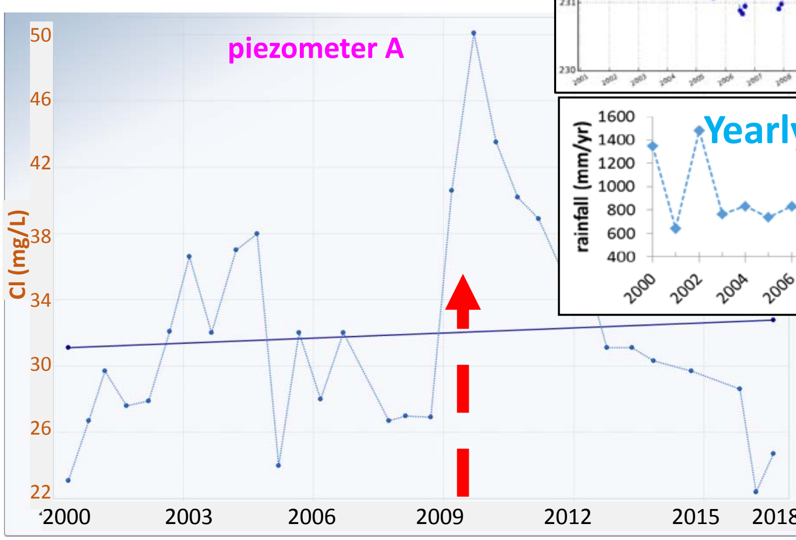


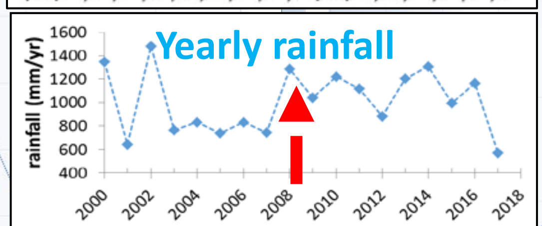


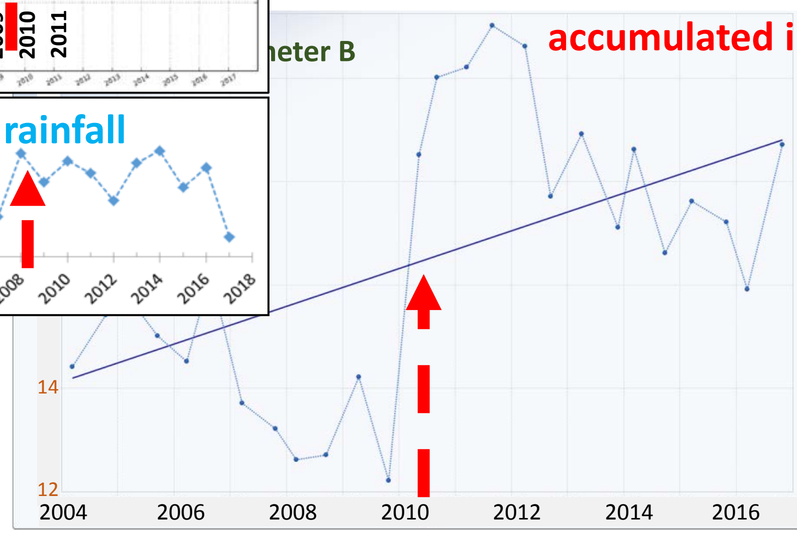


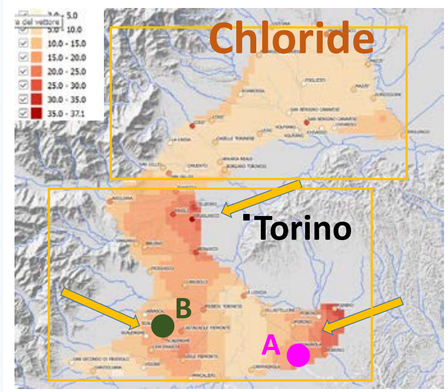


Possible mobilization of salinity and nutrient accumulated in unsaturated zone









Main Conclusions

- This foothill aquifer system consists of a multilayer that has a phreatic aquifer overlying a succession of impermeable and permeable layers. The feeding occurs by infiltration of local rainfall, river seepage and transfers of groundwater that originate in upland zones;
- Groundwater are mainly of the $Ca(Mg)\text{-}HCO_3$ type with a relatively low salinity. However, the relatively high Cl and NO_3 contents observed in some zones of the phreatic aquifer suggest a certain impact from anthropic activities;
- The monitoring data and the trend analyses point out that the system is significantly sensitive to meteo-climate conditions in terms of groundwater quantity and quality;
- Given these features and the strategic role of the system, it is recommended to continue and possibly enhance the monitoring activities, as well as to program specific survey to better understand specific issues, such as the exchange between shallower and deeper groundwater, which represent the main target for drinking supply;
- In these terms the data collected, the information produced and the groundwater flow model developed, represent a good tool to steer next actions.

Tank you